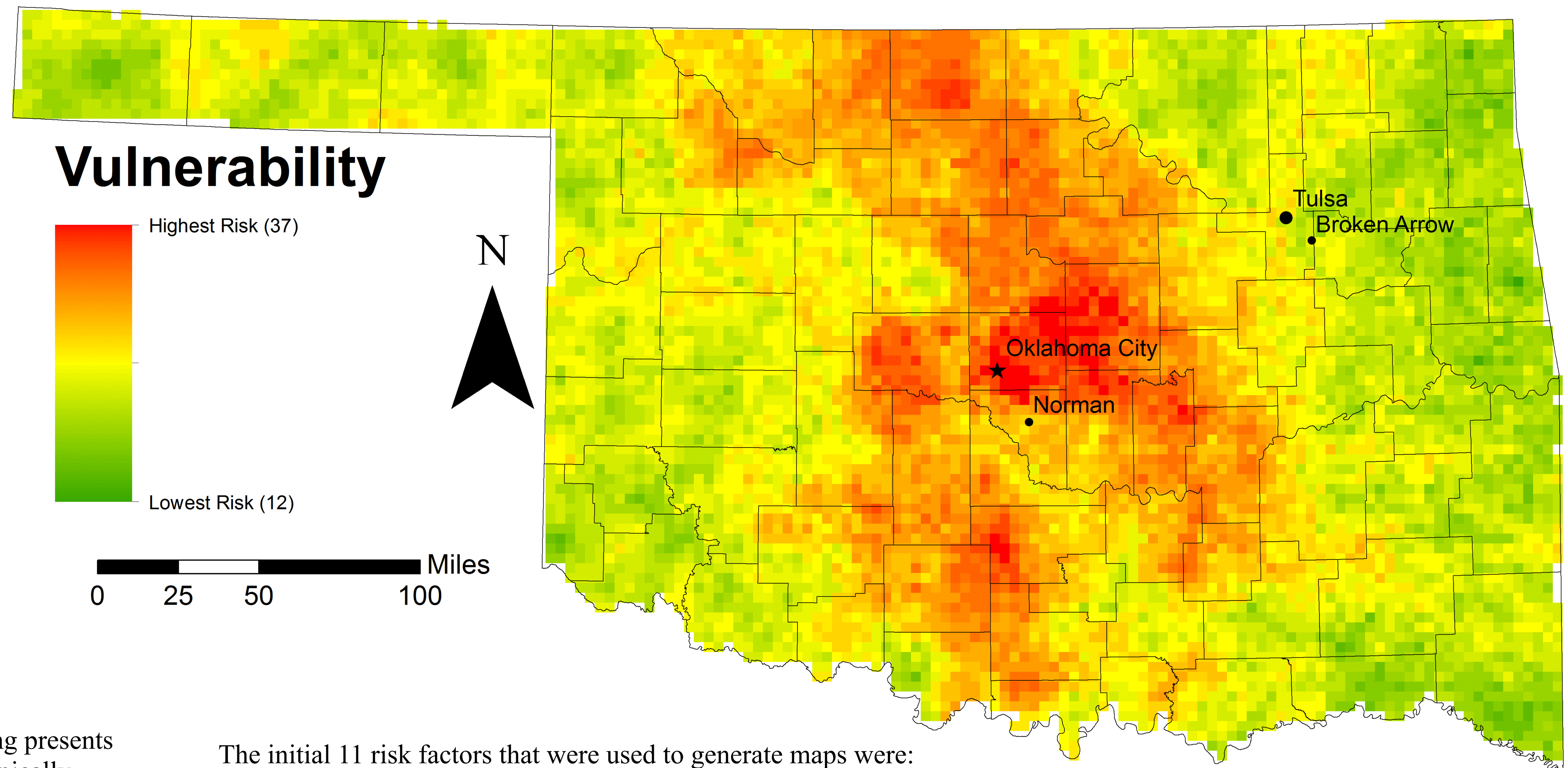
# Where it's not OK to be: Earthquake Vulnerability Analysis in Oklahoma

## Background

Today, hydraulic fracturing, commonly known as fracking, represents one of the most controversial aspects of the energy and fossil fuel industry. Fracking is a process used to reclaim otherwise inaccessible amounts of natural gas or petroleum from solid shale from deep underground. Hydraulic fracturing is named so because the method of fracturing these rocks is the use of a pressurized "fracking fluid" that creates many cracks in the shale that enables natural gas or petroleum that was previous sequestered inside the shale to be withdrawn. A long well is drilled underground until the shale is accessed. The fluid, consisting of a slurry mixture of water, chemical agents, and sand to help hold cracks open, is then injected under high pressures into the well, causing cracks in the rocks. The natural gas and petroleum can then be withdrawn up the pipe. Much of the reclaimed wastewater is later injected back into the ground as a method of wastewater disposal. While fracking presents an opportunity to withdraw energy sources that typically would not be accessible, aiding the economy (and fostering the development of fracking towns), there are a variety of environmental concerns about the process, including concerns about chemicals and gas entering the water supply and noise pollution.

One of the more alarming potential side effects is related to tectonic activity. The fracturing process used can potentially awaken dormant or otherwise unknown seismic lines and cause a dramatic increase in the amount of earthquakes felt in the surrounding area. While the fracking process itself has been connected to outbursts of microearthquakes (magnitudes below 2.0 and typically unnoticed by people), stronger seismic connections have been made with fracking wastewater disposal into deep wells. A prominent example of this can be seen in the state of Oklahoma. A major site for the fracking industry, Oklahoma has experienced a substantial uptick in the amount of noticeable (Magnitude 3.0 or higher) earthquakes since the year 2010. The general location of where these earthquakes is also different than historical earthquakes, occurring in clusters around high densities of fracking wells. Earlier this year, the state experienced the most powerful earthquake in its history, at a magnitude of 5.8. While this pales in comparison to severe earthquakes felt elsewhere in the world, the concern lies in the fact that much infrastructure is not designed to withstand a strong earthquake. In the event that consistent and stronger earthquakes arise in the wake of fracking, Oklahoma could face potential severe damages. The goal of this GIS analysis is to create a composite vulnerability map to attempt to understand which areas of the state may be at the most risk from an earthquake.




The initial 11 risk factors that were used to generate maps were:

- **Predicted ground acceleration values (how the ground itself would impact shaking, with higher acceleration values meaning more potential shaking)**
- **Predicting shaking that could potentially be experienced in general**
- **Land use**
- **Slope**
- **Locations of notable historic earthquakes**
- **Locations of earthquakes occurring between 2005 and 2009**
- **Locations of earthquakes occurring between 2010 and 2015**
- **Locations of sites with toxic releases**
- **Locations of Superfund cleanup sites**
- **Locations of hospitals**
- **Locations of fire stations**
- **Locations of fracking/wastewater injection wells**
- **Locations of fault lines.**

The end goal for each of these risks was to generate raster maps that spatially scored each factor from one to five – with one being least vulnerable and five being the most vulnerable. Depending on the nature of the risk factor, a number of different analyses were run. For factors that were already in raster form (slope, land use, ground acceleration, and predicted shaking), a simple reclassification process was all that was needed to reassign the pixel values to be one through five. For the other risk factors, which were all point based, a new raster needed to be generated. These maps were based off several different factors, including proximity to certain features (fire stations, hospitals, toxic release sites, and superfund sites) and density of occurrence (locations of all earthquakes, locations of fault lines, and locations of wells). Following the creation of these maps, their values would be added using raster calculator, creating the final composite map, with areas with the highest cumulative score having the greatest risk.

## Methods

A composite vulnerability map works by combining factors from many other maps, resulting in a map which adds up the risk from each individual map. In the case of this vulnerability map, 11 other maps were created from individual risk factors that could play a role in determining potential impacts from a large earthquake.


**Map created by: Alex Shimmel**
**12/19/2016**


**GIS 101: Intro to GIS**

**Map Coordinates: NAD 1983 (2011) State Plane Oklahoma North (Meters) FIPS 3501**

**Projection System: Lambert Conformal Conic**

**Sources of Data: USGS, ARCGIS Online, US Census, OKmaps, NLCD, Frackingdata.org**


**Ellsworth, W. L. (2013). Injection-Induced Earthquakes. *Science, 341*(6142), 1225942-1225942. doi:10.1126/science.1225942**

**Hand, E. (2014). Injection wells blamed in Oklahoma earthquakes. *Science, 345*(6192), 13-14. doi:10.1126/science.345.6192.13**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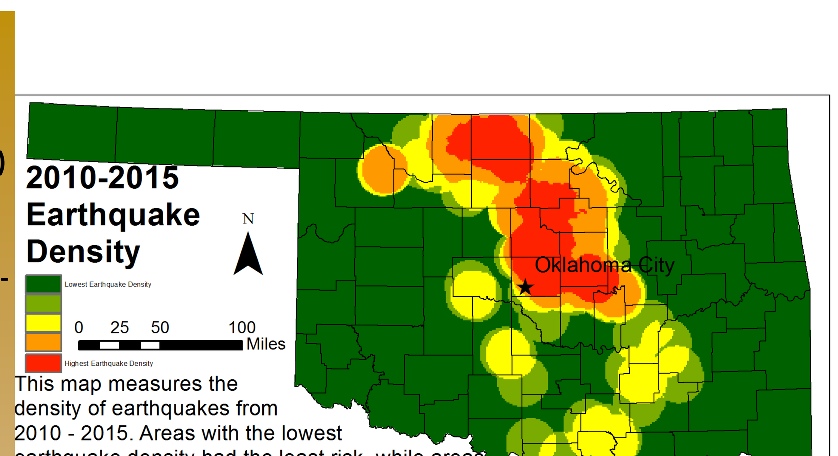
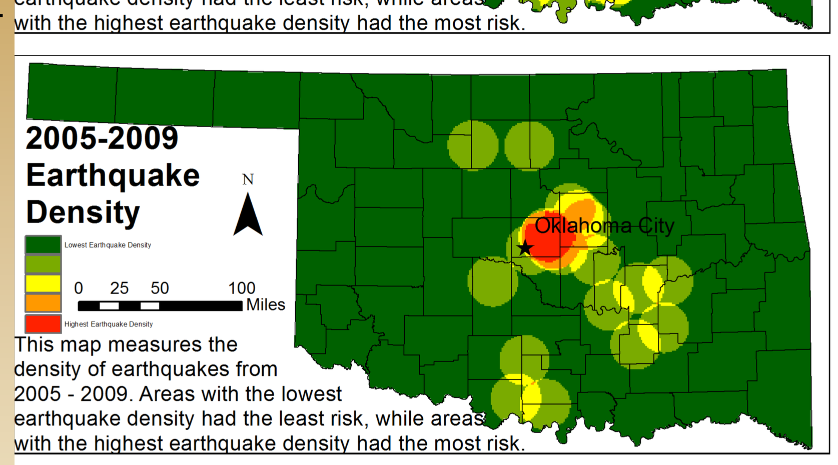
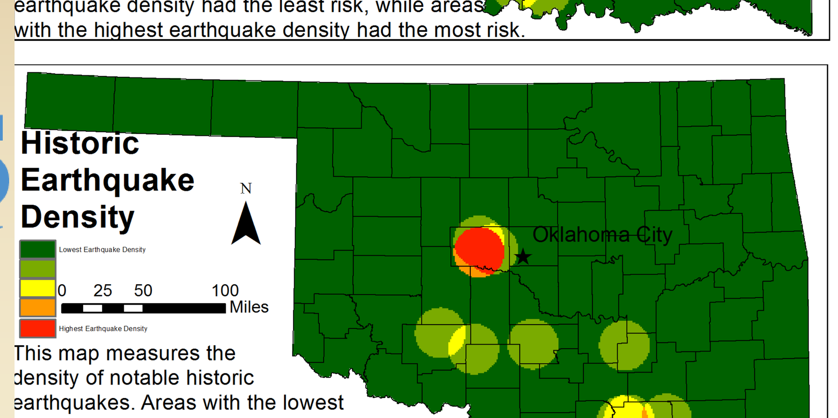


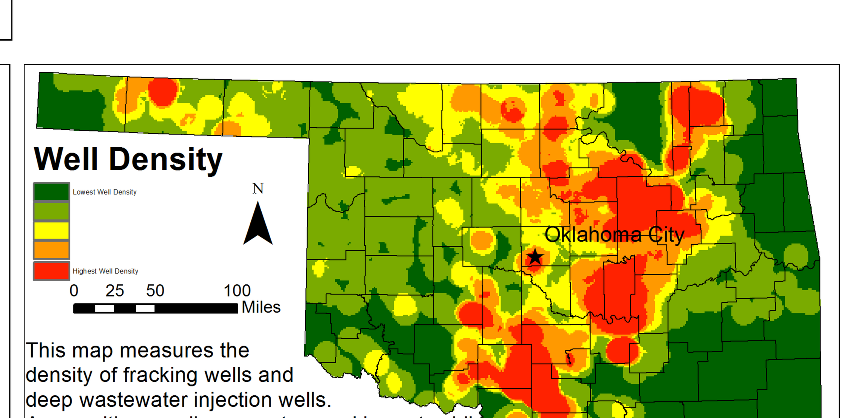



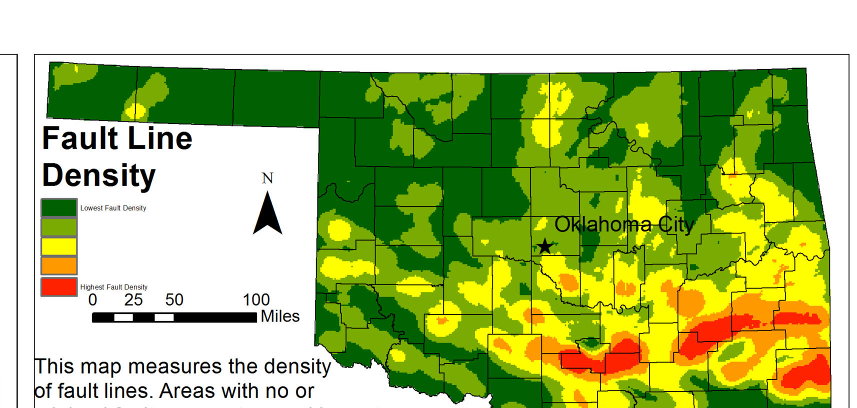




## Results

The results of this analysis show that areas with the highest vulnerability risk to earthquakes include the area around Oklahoma City, south-central Oklahoma, and north-central Oklahoma. Oklahoma City, despite having close proximity to hospitals and fire stations, remains high risk due to scoring high on a variety of different factors, including high general densities of earthquakes and wells, high predicted ground acceleration and shaking, and proximity to many toxic release sites. Oklahoma City scoring as most vulnerable is alarming due to the high population and property values of the area. South-central Oklahoma scores relatively high due to well and historic earthquake densities as well as predicted ground acceleration, while North-central Oklahoma scores similarly high due to well and recent earthquake densities as well as predicted shaking. Some other areas, like Tulsa and the southeastern corner of the state, score high on some factors but remain at moderate to low risk from numerous other factors. The results from this vulnerability map can be used in future analysis for populations as well as property values that fall in high risk areas.

There are numerous improvements that can be made to this map. First, risks can be weighted so that certain risks can be a larger factor in the composite map than others. There are other factors that can also be included to develop a more comprehensive vulnerability map – examples include proximity to highways and soil type. Lastly, some of the initial 11 factors may be worth removing – particularly slope due to the relatively flat nature of Oklahoma. Continued adjustments to this map can allow for it to do a better job of reflecting the most earthquake vulnerable areas of Oklahoma.




## Risk Factors